

**COMPARATIVE ASPECTS OF DIGESTIVE PHYSIOLOGY AND NUTRITION
IN GOATS AND SHEEP**

C DEVENDRA

DIVISION OF AGRICULTURE, FOOD AND NUTRITION SCIENCES

INTERNATIONAL DEVELOPMENT RESEARCH CENTRE

TANGLIN P O BOX 101

SINGAPORE 9124

Paper presented at the Satellite Symposium on Ruminant Physiology and Nutrition in Asia, VII International Symposium on Ruminant Physiology, 28 August to 1 September, 1989, Sendai, Japan.



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C Devendra
Division of Agriculture, Food and Nutrition Sciences
International Development Research Centre
Tanglin P O Box 101
Singapore 9124

Summary

Comparative aspects of digestive physiology and nutrition in goats and sheep are discussed in the context of differences due to feeding behaviour, intake, digestive function, utilisation of nutrients, water economy and turnover rate, and digestive efficiency. Some of these differences are inherent, but others result from adaptation and interaction with various environmental factors. Present evidence suggests that goats are more selective, have a higher intake, rumen volume and gut fill, salivary secretion and rumen ammonia, urea recycling but lower water intake and turnover rate compared to sheep. Increased salivary function and urea recycling may be associated with their ability to have a higher tolerance for tannins. Concerning digestive efficiency, the available evidence suggests that with good quality forages with organic matter digestibility values of about 60% and above, there appear to be no differences between-species. With poorer quality forages and roughages on the other hand, goats appear to digest fibre more efficiently than sheep. Precise reasons for these and a much better understanding of the real differences merit more thorough investigations, but are associated with particle size, salivary secretion, microbial activity, rate of digestion, partition of nutrients, water intake and turnover. These investigations are urgent and justified by the fact that both species are very valuable resources in the developing countries. The implications of the findings relate to factors that govern the choice of species and more complete use of potentially important breeds of goats and sheep, the available feed resources, application of more appropriate feeding strategies, and increased productivity from both species in the future.

(Key words: Goats, sheep, intake, digestive physiology, nitrogen metabolism, digestive efficiency, water turnover, tannins).

Introduction

When considering the production of goats and sheep, it is especially important to keep in perspective their particular abilities in the context of variations in management and environmental conditions, and the effects of these on levels of productivity. Since the latter is greatly influenced by feeding and nutrition, particular attention to this factor is justified. Associated with this, is the

fact that goats and sheep account for approximately 94 and 52% of the respective total world populations in the developing countries (F.A.O., 1986) of which about 56 and 16% are found in Asia. They make a significant contribution to food production, supplementary income and other miscellaneous functions (Devendra, 1987a; 1888). However, efforts to increase the contribution from these production resources are generally constrained by inadequate attention and priority for research and development within national programmes with specific attention to feeding and nutrition.

Additionally, there is also the point that until relatively recently, most studies especially on digestive physiology, feeding and nutrition have tended to focus on one or the other species, rather than experiments that involve both species simultaneously. In this context, comparative experimentation on nutrition offers considerable potential for making much more rapid progress (Devendra, 1987b), and providing for much better understanding of the significance of nutrition on productivity in goats and sheep. Good justification for this approach is reflected in the fact that goats and sheep are often herded and managed together in the developing countries, and that their feeding and nutrition are quite complementary.

The intent in this paper is to make a comprehensive review of current understanding of comparative digestive physiology and nutrition in goats and sheep, draw attention to major attributes in both species and allude to the direction for continuing research in this field.

Comparative Differences in Nutrition

Goats and sheep do have differences that are characteristic of the species. The differences relate to feeding behaviour, aspects of digestive function and utilisation of nutrients. Many of these features, and especially the aspects related to digestive physiology are not well understood. The differences are nevertheless sufficient to warrant a different standard on nutrient requirements for goats (N.R.C., 1981) compared to sheep. Similarly, the differences in feeding behaviour and utilisation of nutrients suggest that although they may be herded together for grazing, management and feeding

strategies need to take cognisance of the apparent and real differences in order to ensure high performance in both species.

Table 1 brings together comparative differences in feeding behaviour and nutrition, based on the available knowledge. Some 16 main differences are identifiable, but these are by no means exhaustive or meant to be complete. The list does provide however, the main differences, inherent, and in response to the environmental factors.

Several differences are worth emphasising. These include in the goat, the bi-pedal stance (Malachek and Provenza, 1981), relatively higher activity, distinctly greater preference for more variety of herbage, but is reduced with increasing intensification. Under stall-feeding conditions, goats and sheep are also selective, but the former had a greater intake of roughages (Wahed and Owen, 1987). Other differences are related to taste, water economy, dehydration, salivary secretion, recycling of urea and digestive efficiency.

Goats are essentially browsing animals, and by comparison, sheep are grazing animals. Goats have a competitive advantage over sheep in woodland and shrubland, are generally more active, selective, walk longer distances in search of feed and relish variety in feeds (Devendra, 1987c). Thus they are natural leaders of mixed goat and sheep flocks in many developing countries. Sheep are less selective and utilise pasture more effectively. Another feature of the feeding behaviour of goats is their discerning ability to taste. Goats can distinguish between bitter, sweet, salty and sour tastes, and show a higher tolerance for bitter taste than do sheep and cattle (Bell 1959; Goatcher and Church 1970). Additionally, some desert goats such as the Egyptian Zaraiby are known to have lower resting metabolic rate than would be predicted from the known equations relating body weight, metabolic rate and surface area (Salem *et al.*, 1982). Such an adaptation is advantageous of life in arid zones where water and feeds are scarce.

Comparative observations on browse between goats and sheep in the arid zones of Mexico concerning 1728 goat bites in a mixed brush-grass-forb community revealed that 83% of the bites were on browse and

forbs, and 17% on grass (Carrera, 1971). It appears likely that the higher nutritive value of some browse accounts for a greater net daily intake of nutrients by goats than by cattle or sheep (Short et al., 1973; Cardova and Wallace, 1975; Rector and Houston, 1976). By comparison in Australia, Wilson et al. (1975) used oesophageal fistula to study the food preferences of captive feral goats compared with sheep at three grazing pressures (0.5, 0.25 and 0.17 animals per hectare). At low stocking rates, sheep ate 80% herbs and 20% browse, while goats ate the reverse. At medium and high stocking rates, availability of herbs governed intake. Goats tended to select diets with appreciably higher nitrogen content than sheep, but in vitro digestibility of the nitrogen was not always as high.

Recently, studies have been reported on dietary selection by goats and sheep in deciduous woodland in northeastern Brazil. During the dry season (May-Dec) sheep and goats selected similar diets. During the wet season (Jan-Apr), sheep selected mainly grasses and forbs, while goats rapidly shifted among grasses, forbs and browse (Pfister and Malechek, 1986). In Kenya (Field, 1979) reported that the following forage fractions were eaten as percent in the diet by goats and sheep respectively: trees 14.9 and 2.6, shrubs 37.5 and 30.4, herbs 22.0 and 29.6 and grass 25.0 and 36.9%.

In high quality pastures, where browse is not present, there is increased competition between species for components of the sward. Sheep appear to prefer clover much more than goats, and Clarke et al. (1982) have suggested that sheep eat white clover in proportion to that on offer in the sward while goats reject white clover. However, Hughes et al. (1984) have not been able to demonstrate this in limited diet selection studies, but adult goats have been observed to have a lower proportion of clover.

Digestive Function

Associated with the differences in feeding behaviour and nutrition, are a number of aspects related to digestive function. Of particular importance in this connection are comparative patterns of rumen digestion, salivary secretion, nitrogen and ammonia transactions, possible differences in microbial populations, water intake, flow

through the digestive tract and turnover. It is appropriate to review these aspects briefly.

Fundamental to any differences in digestive function is intake. The general conclusion that emerges from a review of the literature is that goats have a relatively higher intake than sheep. One example of this result is shown in table 2. Not all the differences were significant, and the ratio of digestible organic matter intake (DOMI) goats compared to DOMI sheep indicated that differences greater than 15% began to occur at organic matter digestibility below 60%. The relatively higher intake also supports the finding based on a review of the literature (Devendra and Burns, 1983) that adult meat goats in the tropics had a dry matter intake of up to 3.8% of body weight and dairy goat breeds up to 4.7% of body weight. These data are generally higher than corresponding values for adult sheep in the tropics.

Recent findings by Tan (1988), indicate that the higher intake of goats compared to sheep was not due to a higher rumen digestion rate, but was accompanied by a significantly higher rumen volume (0.23 vs 0.14 l/kg live weight) leading to a larger rumen fill of dry matter (25.8 vs 15.7 g/kg live weight). The significantly higher rumen volume in goats confirms a similar report in Australia (Watson and Norton, 1982), which was accompanied by a longer mean retention time. With high quality forages, it was concluded that there may be little difference between-species in partitioning of nutrients, digestion of dry matter, neutral detergent fibre and non-ammonia nitrogen (Alam et al., 1985). The same studies also showed that there were no major differences between species in the site of protein digestion.

The higher intake of dry matter is associated in turn with nitrogen utilisation, and in goats, there appears to be higher rumen ammonia levels compared to sheep (Watson and Norton, 1982; Alam et al., 1987, Tisserand et al., 1986; Tan, 1988), and is probably related to a longer retention time of digestion in the rumen and lower water intake. It has been suggested that this might be advantageous in the digestion of low quality herbage (Watson and Norton, 1982). Tan et al. (1989) have recently concluded that higher rumen ammonia levels in goats did not confer any advantage in terms of digestion rate and duodual protein

supply.

There also appear to exist differences in saliva secretion between goats and sheep when given the same feed, with production rates of 848 ml and 502 ml/day respectively (Seth *et al.*, 1976). Differences in saliva secretion are likely to influence urea recycling, an important factor in fibre digestion. Harmeyer and Marten (1980) have shown that sheep and goats have a much superior capacity to recycle urea than cattle. Additionally, the relatively higher secretion of saliva and urea recycling, together with reduced water intake in goats predispose this species to nitrogen conservation. The latter aspect is likely to render the species more tolerant to poor quality feeds with low nitrogen content and is consistent with their ability to utilise these more efficiently than sheep. There appear to be important breed differences in urea recycling; Black Bedouin goats recycled 0.18 g N-urea/kg liveweight which is twice that produced by Saanen goats fed the same diet (Silanikove *et al.*, 1980).

Water Economy and Turnover Rate

The water economy, flow through the digestive tract and turnover rate are important indices of adaptation to various environments by a species and even breeds within a species. Water turnover is influenced mainly by species, age, environmental temperature, feed supply and lactation.

In semi-arid and arid climates, water supply is minimal and dehydration is inevitable. Water is conserved by ability to resist dehydration and by producing concentrated urine, dry faeces and reducing evaporative water loss. Goats, camels and asses show tolerance of dehydration up to 20% of their body weight and this is associated with their ability to maintain constant plasma volume and hence also circulation. Khan *et al.* (1978) found that after four days of absolute water deprivation, goats lost body weight at the rate of 1.5%/day, compared with 8% for cattle, 4-5% for Merino sheep and 1% for camels, suggesting that goats are better adapted to water deprivation than sheep or cattle.

Goats and camels have an efficient mechanism to conserve water

through resistance to dehydration and reduced water loss in faeces and urine. In both species the urine is concentrated. Bedouin goats can replenish all their water loss in a few minutes by consuming up to 40% of their liveweight (Maltz and Shkolnik, 1980).

Awassi sheep and the German Mutton Merino sheep breeds have been shown to reabsorb water from the alimentary tract at about the same rate. However, the Awassi excreted more concentrated urine and retained 84% of their plasma volume compared to 75% in the Merino. It was also reported that the Awassi retained 97% of the water consumed in a single drink compared with 64% in the Merino (Degen, 1977a; 1977b). These results suggest that there are breed differences.

Total water intake in goats (free-water plus feed-water) appear to be lower in goats compared to sheep. The implications of a reduced water intake in goats are not entirely clear, but appear to be associated with nitrogen conservation and utilisation, higher rumen $\text{NH}_3\text{-N}$ concentration, longer retention time and digestive efficiency. Alam *et al.* (1987) concluded from a comparison of kids and lambs, that a lower water intake in the former was associated with a greater net addition of water to digestion across the rumen and omasum-abomasum. The greatest net water absorption occurred in the small intestine of both kids and lambs, with about 24% of that entering the small intestine being absorbed in both species.

The lower water intake in goats is consistent with a lower water turnover rate and is apparently advantageous to lactating animals. In the Negev desert of Israel, Black Bedouin goats have been reported to produce 80-90% of their body weight in milk per lactation which was associated with the water turnover rate being twice as high as in non-lactating goats. This was achieved by the goats increasing their total body water by 35% over the non-lactating period. During dehydration, milk yield was only affected 48 hours post-dehydration for which reason these goats are only watered every 2 to 4 days (Maltz and Shkolnik, 1980). During dehydration, plasma volume decreased in proportion to total body fluids indicating ability to balance both gain and loss of body fluids. Repeated periods of water deprivation had no effect on the Bedouin goat's ability to resume full milk production, which within

three days of rehydration returned to normal. Brosh et al. (1986) also showed in the same goats that four days of water deprivation reduced the rate of fluid flow through the reticulo-omasal orifice by up to 80%. The animals maintained feed intake during dehydration (Shkolnik et al., 1980) and it has been suggested that the rumen also served as a water reservoir.

Digestive Efficiency

This subject and possible differences between-species was first discussed over a decade ago (Devendra, 1978). It has since been reviewed in detail (Devendra and Burns, 1983), involving 32 comparisons between goats and sheep, goats and cattle or buffaloes. Of these, 22 showed statistically significant differences in favour of higher digestive efficiency for cellulose by goats, three showed higher efficiency in sheep, and in one steers were the more efficient. Since this review, a few additional comparative studies have also been reported on intake and digestibility between goats and sheep (see for example Alam et al., 1984; Tisserand et al., 1986; Tan, 1988).

Tables 3 and 4 present results from Watson and Norton (1982) and Tisserand et al. (1986). In the former case, although there were no significant differences in intake, goats digested the acid detergent fibre (ADF) to a significantly greater extent ($P < 0.05$) than sheep. The results of Tisserand et al. (1986) on the other hand show a higher intake, conspicuous differences in the disappearance of ADF and total anaerobic flora.

The results together lead to the following conclusions:

- 1) With good quality forages, with organic digestibility values of about 60% and above, there appear to be no differences in digestibility values between goats and sheep. The digestibility data derived from one or the other species can therefore be mutually applied. Evidence for this is seen in the data on tropical feeds (Sharma and Murdia, 1974; El Hag, 1976; Devendra, 1977), and also temperate forages (Jones et al., 1972; de Simiane et al. 1981; Gamble and Mckintosh, 1982; Watson and Norton, 1982; Doyle et al. 1984; Brown and Johnson, 1984; Alam et al., 1985).

- 2) With poorer quality forages and roughages, including browse and tree fodders, present evidence suggests that goats are more efficient than sheep in their utilisation. In these circumstances, the digestibility data derived from one species cannot be applied on the other. This feature is reflected in the results of Hossain (1960), Devendra (1975), Wilson (1977), Gihad et al., (1980) and Carvalho and Bueno (1987).
- 3) In many parts of Asia, as well as other developing countries, poor feeding regimes involving low quality forages and roughages is the norm rather than the exception. In these situations, it is probable that the ability of goats to make more efficient use of the feeds, make them potentially more important animal in terms of resource use and contribution. For this latter reason and also differences in feeding behaviour, there are differences in the allocation of nutrients for these species.

It is stressed however that the first two conclusions await elucidation and discussion through more concerted research, especially on aspects of digestive function. Clearly, several factors are involved to explain the apparent improvement in digestive efficiency with poor quality forages, including their interactions. These include inter alia: feed particle size, amount of salivary secretion, rumination, concentration of cellulose splitting micro-organisms, fermentation rate, absorption capacity, recycling of urea, rate of digestion and passage, retention time, water intake, flow through the digestive tract and turnover.

Tannins

Tannins and other deleterious principles are common in many shrubs and tree fodders. The problem is more acute for browsing animals like goats which thrive on these feeds much more than sheep. However, goats appear to be more tolerant of tannins than sheep, but real reasons for this are not fully understood, but it has been suggested that the increased salivary function produces mucins that bind tannins and spare the protein for digestion (Hoffman, 1987).

Choice of Species

Given the foregoing, the rapid growth of the goat and sheep populations in Asia, and competition for feed resources, the questions that can be asked is what is the future for small ruminant production and their potential contribution in the future? Clearly some careful planning and direction for development is necessary in the context of efficient utilisation of the available resources. In analysing this, one important consideration is the choice of species and their relative importance in individual countries, and situations within the country.

The following issues are considered important in the choice of species :

- 1) Feeding behaviour : goats are inquisitive animals and essentially browsers (Devendra and Burns, 1983; Devendra, 1987). This feature enables a greater selection intensity than sheep which by comparison, are grazing animals. In situations where there is less grass and a higher proportion of shrubs and other forages, goats are likely to make more efficient use of this herbage. Sheep are generally more docile than goats. Quite often, both goats and sheep are run together to enable maximum utilisation of the available herbage.
- 2) Relative price of meats : the relative price of either goat meat or mutton has an important bearing on the choice of animals. Presently, the price of goat meat is very much higher and approximately 2-3 times than that of mutton, simply because of inadequate supply.
- 3) Availability of animals : the availability of animals for breeding and therefore for slaughter, is an important consideration. Sheep are more easily imported than goats currently, which favours the former in development programmes. On the other hand, there is a high demand especially for good quality breeding goats at high prices.
- 4) Survivability : survivability is an important characteristic and is breed specific. It is an important component of biomass

production and life time productivity.

- 5) Market for meats : both goat meat and mutton have a high income elasticity o. demand and this is particularly apparent in the Near East markets. The attendant factors that merit consideration are type of meat required (goat meat or mutton); methods of slaughter, processing and costs of transportation, live animals or frozen carcasses; carcass quality and taste preferences; and economic benefits of the export trade.

Conclusions

Present evidence on comparative aspects of digestive physiology and nutrition in goats and sheep suggests there exist distinctive differences between the species. Some of these are inherent, while others are due to adaptation and also interaction with environmental factors. Progress has been made to seek a better understanding of the differences due to intake, rumen conditions and function, rate and digestion of nutrients, nitrogen transactions, microbial activity, water intake, flow through the alimentary tract and turnover. Differences due to digestive efficiency relate only to low quality forages and roughages, and although the results are inconclusive and occasionally conflicting, goats appear to utilise these feeds much more efficiently than sheep with a concurrent higher threshold for tannins.

The implications of understanding these issues and promoting improved feeding and nutrition in both species is that more efficient resource use can be identified with increased economic productivity. Comparative digestive physiology and nutrition offers considerable scope for striving towards this objective, and in turn, this would also enable much more effective use of several potentially important breeds of goats and sheep, throughout the developing countries.

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TABLE 1

**COMPARATIVE FEEDING BEHAVIOUR AND DIGESTIVE
PHYSIOLOGY IN GOATS AND SHEEP**

Characteristics	Goats	Sheep
1. Activity	Bipedal stance and walk longer distances	Walk shorter distances
2. Feeding pattern	Browser, more selective	Grazer, less selective
3. Browse and tree leaves	Relished	Less relished
4. Variety in feeds	Preference greater	Preference lesser
5. Taste sensation	More discerning	Less discerning
6. Salivary secretion rate	Greater	Moderate
7. Recycling of urea in saliva	Greater	Lesser
8. Dry matter intake : - for meat - for lactation	3% of B.W. 4-6% of B.W.	3% of B.W. 3% of B.W.
9. Digestive efficiency	With coarse roughages higher	Less efficient
10. Retention time	Longer	Shorter
11. Water intake/unit DMI	Lower	Higher
12. Rumen NH ₃ concentration	Higher	Lower
13. Water economy - Turnover rate	More efficient - Lower	Less efficient - Higher
14. Fat mobilisation	Increased during periods of feed shortages	Less evident
15. Dehydration - Faeces - Urine	Less water loss More concentrated	Relatively higher water loss Less concentrated
16. Tannins	More tolerance	Less tolerance

TABLE 2. APPARENT OM AND NDF DIGESTIBILITY AND DOMI (g/kg W^{0.75}/day) BY GOATS AND SHEEP. SIGNIFICANCE LEVELS APPLY TO SHEEP V GOAT COMPARISONS (Alam *et al.*, 1985)

	Meadow hay 1	Meadow hay 2	Prai- rie grass hay	Rye- grass hay	Rye- grass hay	Cocks- foot straw	Bar- ley straw	Mean
<hr/>								
DOMI ¹								
Goats	28.8	43.5	41.3	34.7	23.6	24.2	19.8	28.7
Sheep	23.4*	46.5	<u>40.2</u>	<u>29.1</u>	<u>20.7</u>	<u>14.9*</u>	<u>16.5</u>	24.3**
SED	3.96	2.49			3.72			1.52
<hr/>								
OMD ²								
Goats	0.68	0.77	0.67	0.58	0.53	0.46	0.50	0.55
Sheep	0.55**	0.73*	<u>0.64</u>	<u>0.58</u>	<u>0.54</u>	<u>0.46</u>	<u>0.51</u>	0.55
SED	0.013	0.021			0.022			0.009
<hr/>								
NDFD ³								
Goats	0.61	0.80	0.70	0.64	0.52	0.46	0.56	0.57
Sheep	0.41**	0.78	<u>0.67</u>	<u>0.65</u>	<u>0.54</u>	<u>0.48</u>	<u>0.59</u>	0.59
SED	0.027	0.022			0.026			0.012

¹ Digestible organic matter intake

² Organic matter digestibility

³ Neutral detergent fibre

** P<0.01

TABLE 3. MEAN VALUES FOR THE INTAKE, DIGESTIBILITY AND N UTILISATION OF
PANGOLA GRASS HAY AT TWO STAGES OF REGROWTH
(Watson and Norton, 1982)

	Sheep		Goats		SE of Mean
	I	M	I	M	
O M Intake (g/kg ^{0.75} /d)	47.8a*	31.9b	49.5a	32.6b	2.8
Apparent Digestibility (%)					
- Organic matter	61.4a	53.3b	63.0a	58.3c	0.7
- NDF	73.4ac	63.5b	75.3a	71.3c	1.2
- ADF	63.0a	52.5b	66.9c	63.3ac	1.2
- N	60.0a	24.4b	63.7a	29.5b	2.3
Faecal N (mg/kg ^{0.75} /d)	426a	245b	402a	236b	22
Urinary N (mg/kg ^{0.75} /d)	404a	112b	426a	115b	19
N balance (mg/kg ^{0.75} /d)	238a	-31b	292a	-17b	41
(g/kg DOM)	8.1a	-1.8b	9.4a	0.9b	1.2

* Mean within a line with different superscripts differ significantly (P < 0.05)

TABLE 4. COMPARISON BETWEEN RUMEN ACTIVITY IN GOATS AND SHEEP FED
SOCIUM HYDROXIDE TREATED STRAW
(Tisserand et al., 1986)

Parameter	Goats	Sheep
Level of intake (g D.M./kg $W^{0.75}$)	53.7	36.0
Disappearance of A.D.F.	59.0	13.5
Volatile fatty acids (m mol/l)	60.8	27.1
Total anaerobic flora	9×10^8	5×10^8
Protozoa	4×10^5	1.3×10^5